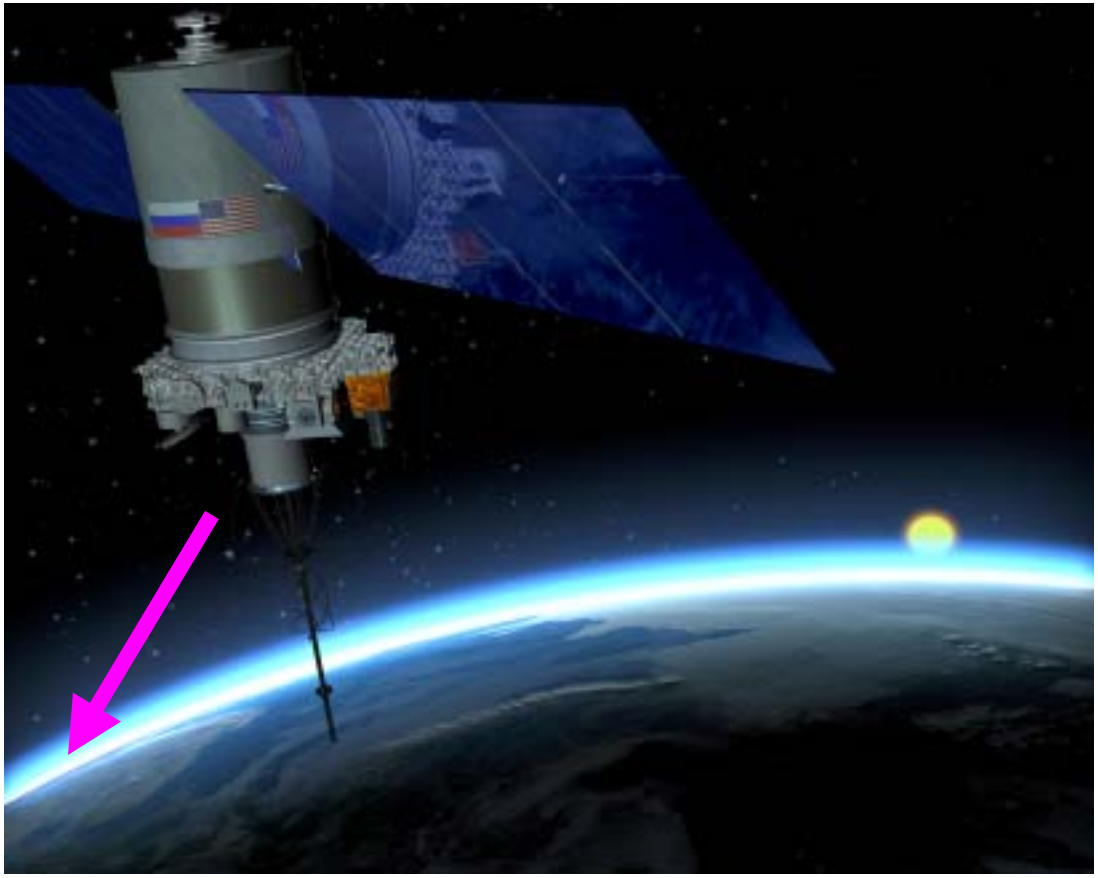
SAGE III Limb Scattering Measurements Initial Results

Didier Rault, NASA Langley Research Center



Solar Occultation Satellite Science Team Meeting

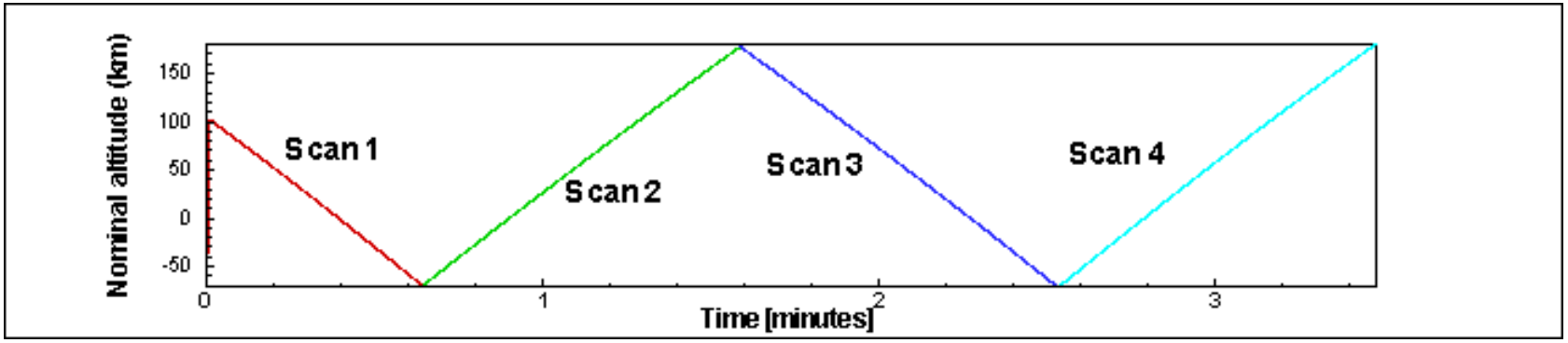
Williamsburg, Virginia
May 6-7, 2003

Outline

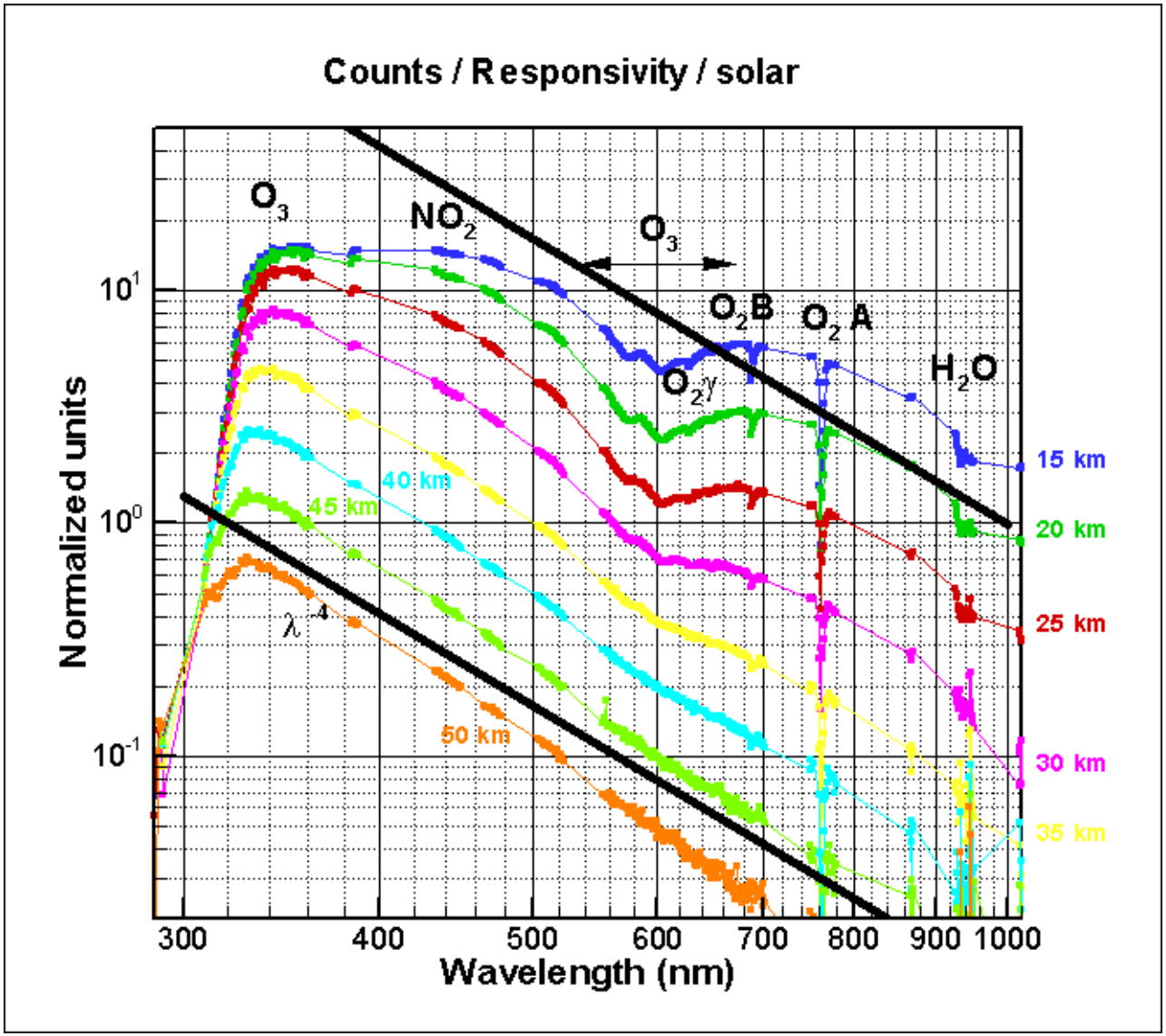
- Limb mode of operation
- Data description
- Stray light issue
- Retrieval methodology (Ozone)
- Retrieval products. Comparison with correlative measurements
- Conclusion

SAGE III in limb mode operation

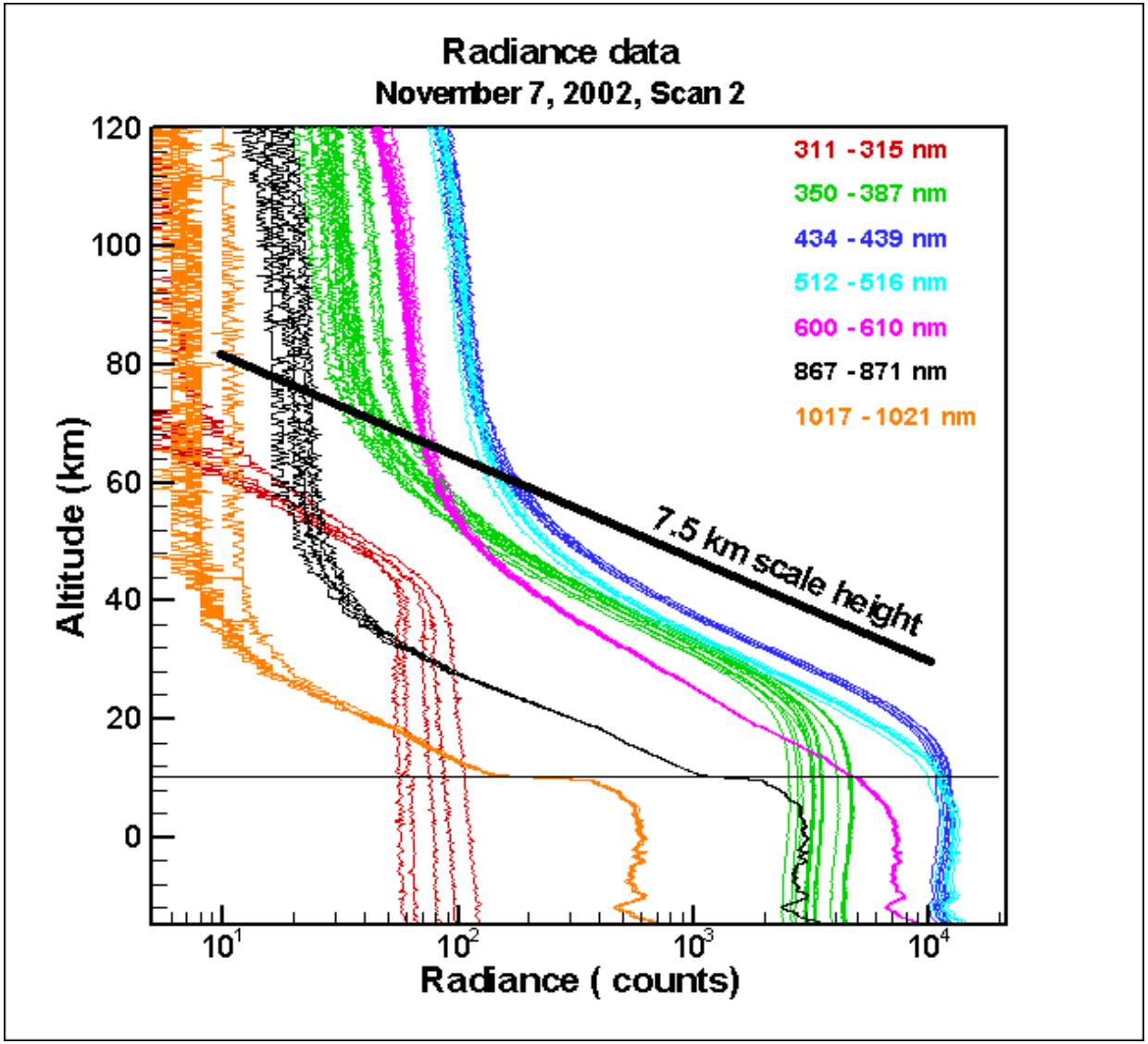
- 340 pixels to cover UV, NO_2, Chappuis, O_2 (A,B,γ), H_2O, Aerosol
- Long integration time = 1/16 second
- Field of View = 0.5 km (elevation) x 4 km (azimuth)
- Slow scanning rate = 4 arc minutes / sec (0.25 km / clock)
- Scan from nominal –70 km to 160 km
- Scan in the aft direction (anti Ram, look azimuth = 180°)
- Limit to 5 minute measurement duration (thermal issues)
- Phase 1: occasional limb measurements (Ozone sondes, SOLVE, SOLSE/LORE, SAGE III occultations)
- Phase 2: One limb scattering measurement per orbit (no Moon)
- Phase 3: Continuous limb measurements on sunlit side of orbit



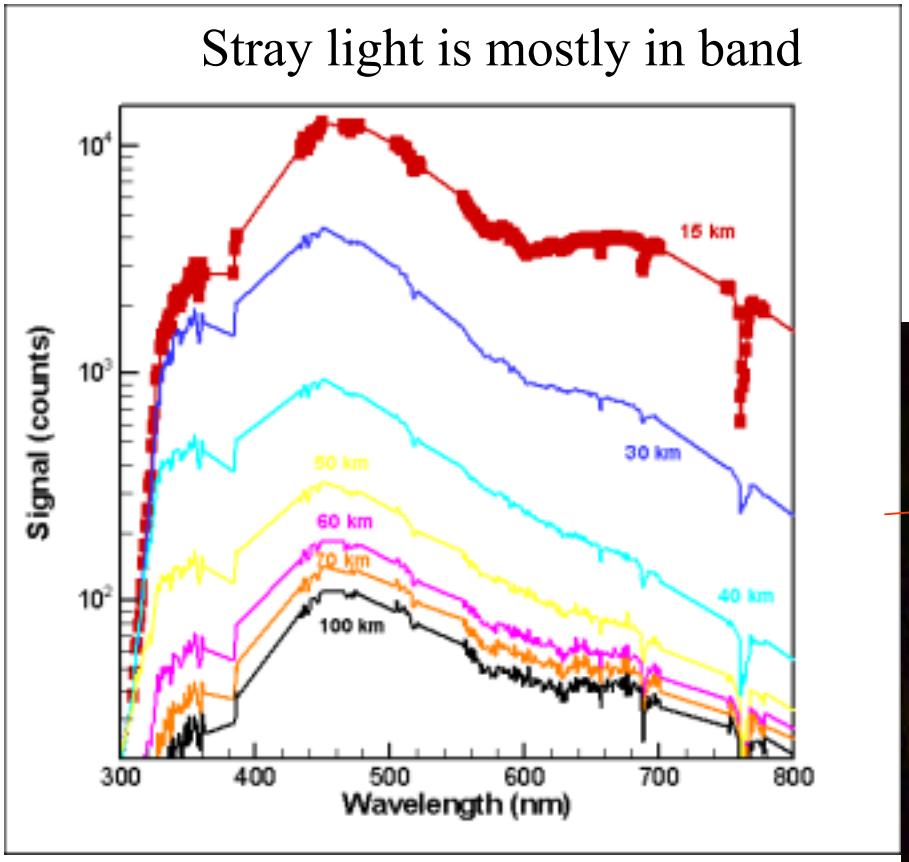
Normalized radiance

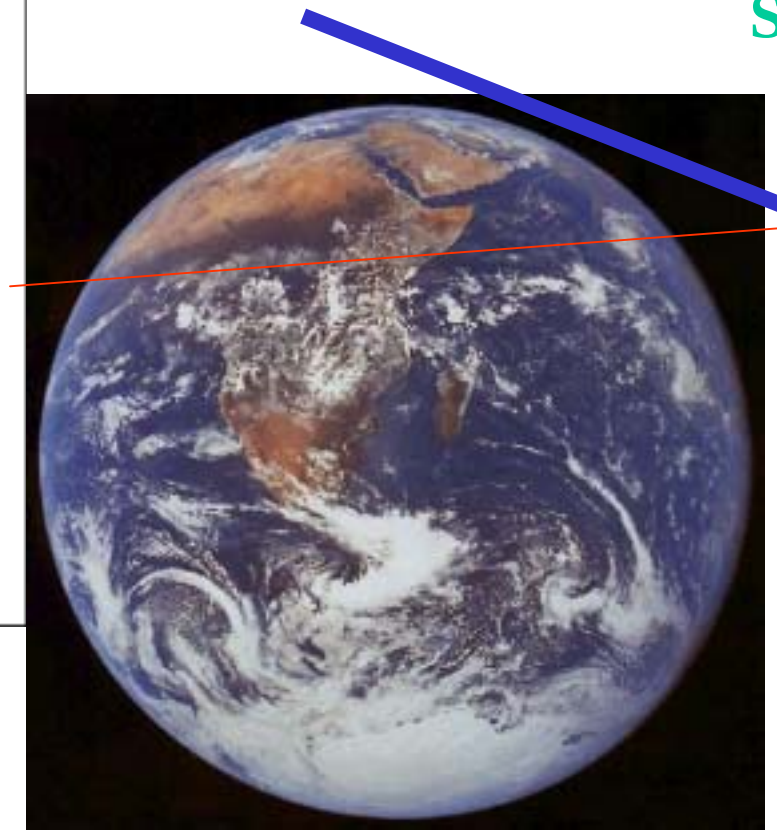


Radiance Data
November 7, 2002



Stray light


Stray light is mostly in band
Signal (counts)
10^4
10^3
10^2
15 km
30 km
50 km
60 km
70 km
40 km
100 km
300
400
500
600
700
800
Wavelength (nm)


SAGE III
Scan mirror

Effective mirror slit function analysis

For every tangent height i, the measured data R_0 is related to the "actual" data R:

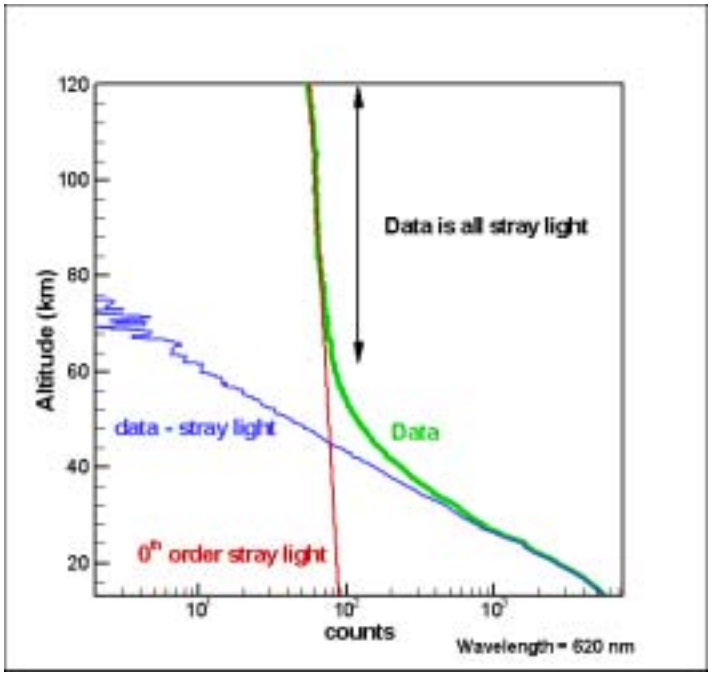
$\mathbf{R_0(i) = \int R(x) \,.\, F(i\text{-}x)\, dx}$, where F is the effective slit function

$= \omega_1 \,.\, R(i) + \omega_2 \,(R(i+1)+R(i-1)) + \ldots\ \omega_j \,.\, (R(i+j-1)+R(i-j+1)) + \ldots$

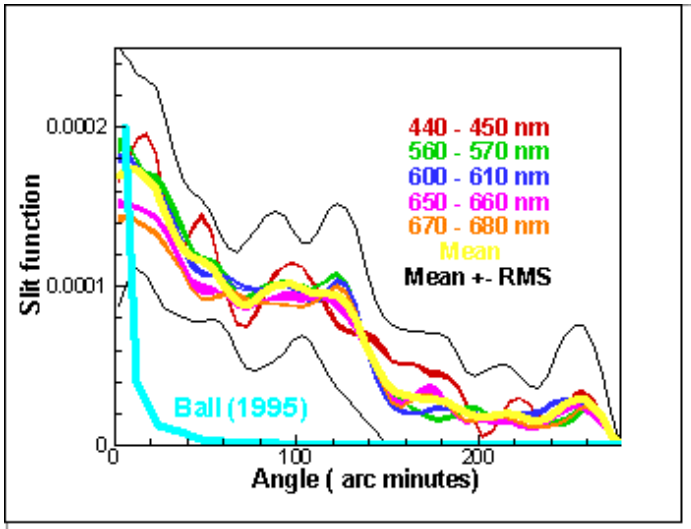
Hence $[R_0] = [A] \,.\, [\omega]$, where $A(i,j) = R(i+j-1)+R(i-j+1)$

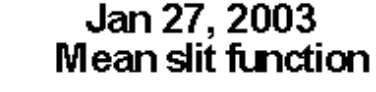
and $[\omega] = [A]^{-1} \,.\, [R_0]$

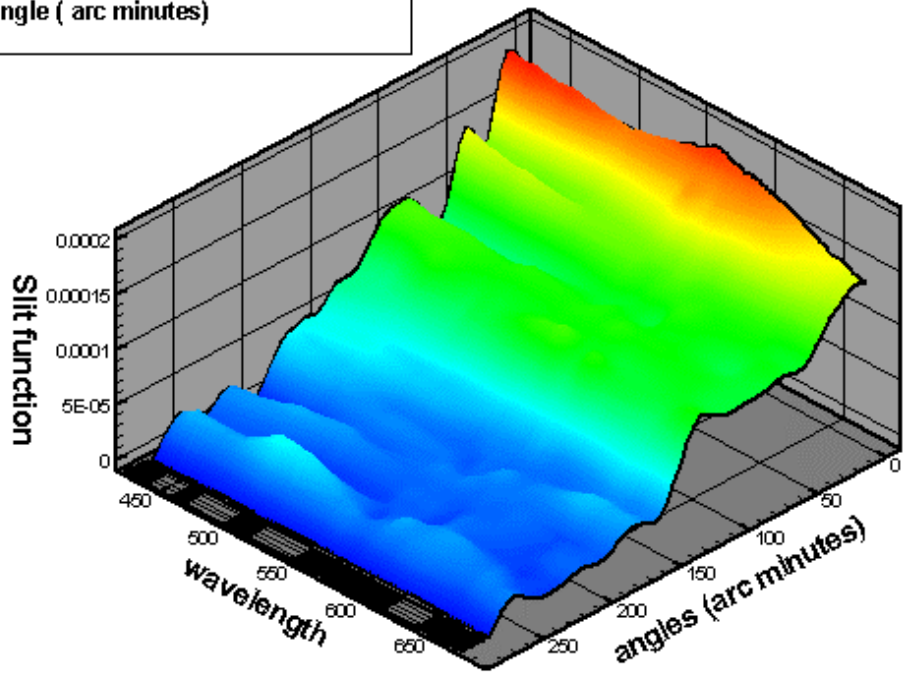
Solved by Singular Value Decomposition



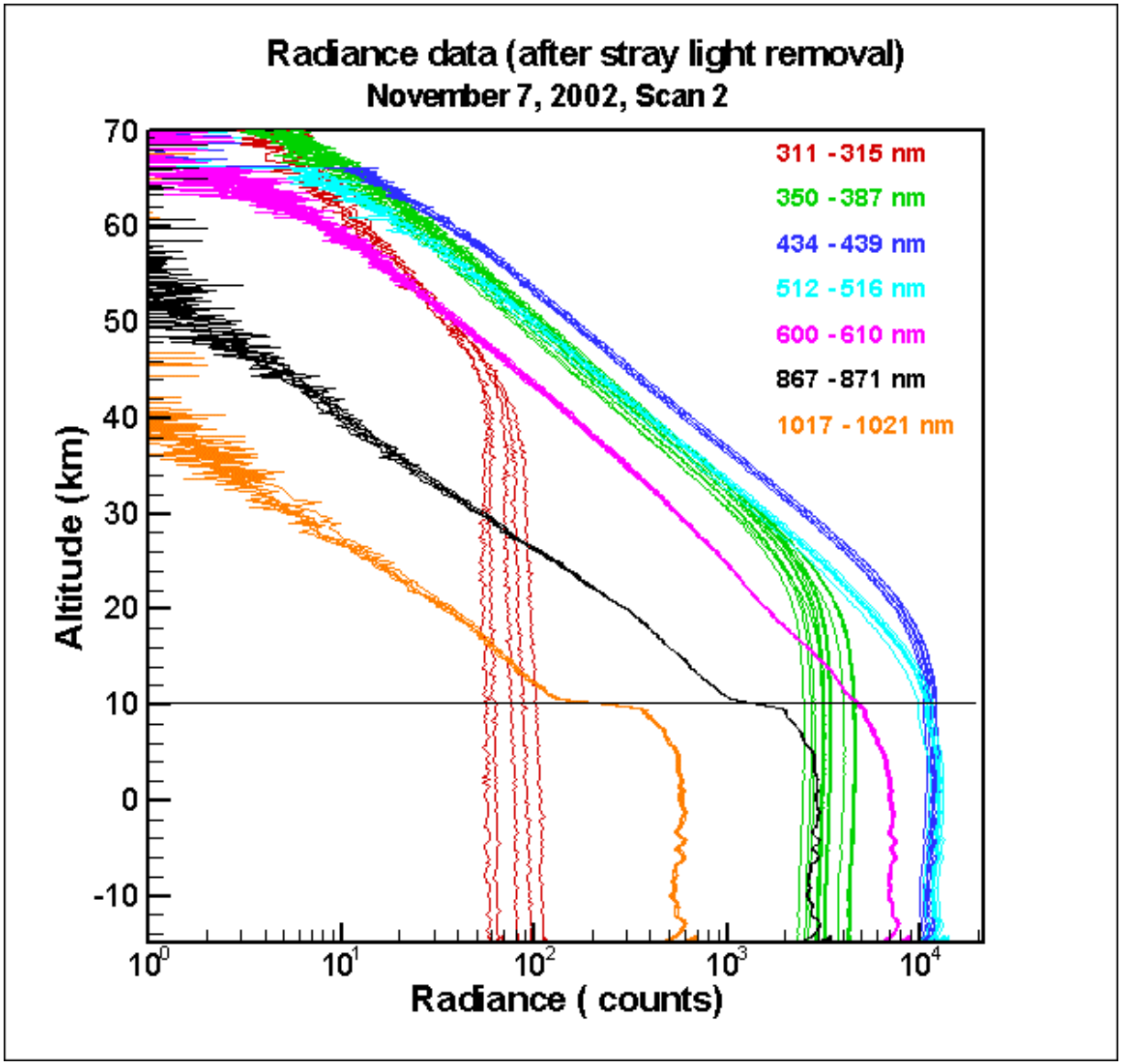
Mean Slit Function
January 27, 2003







Radiance Data
After stray light removal



Ozone retrieval methodology

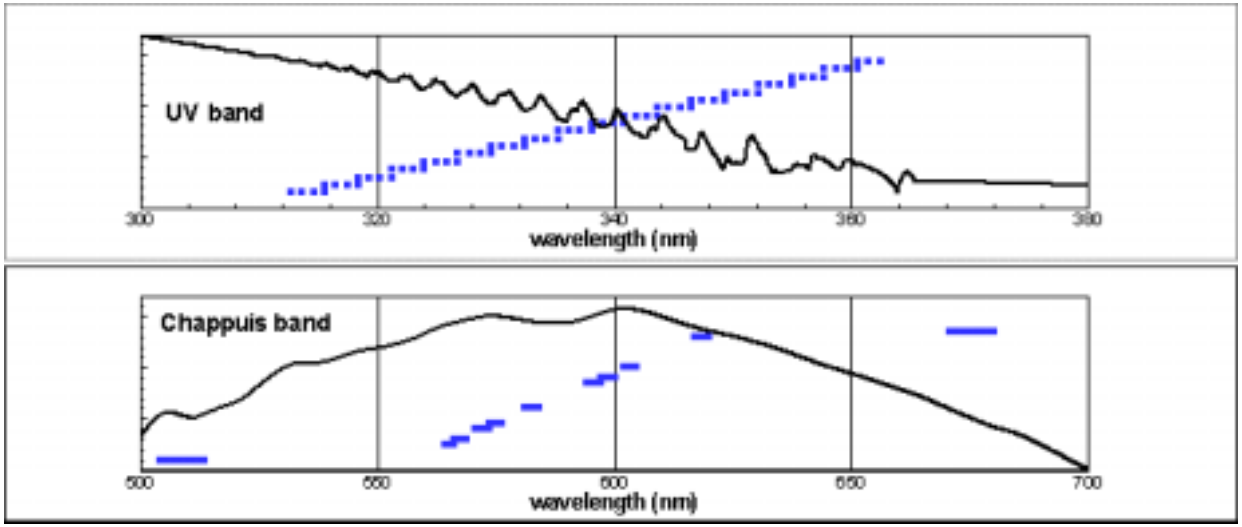
- **Differential method**:

.Flittner's Triplet/Singlet concept

.Series of Triplets in Chappuis band and Singlets in UV

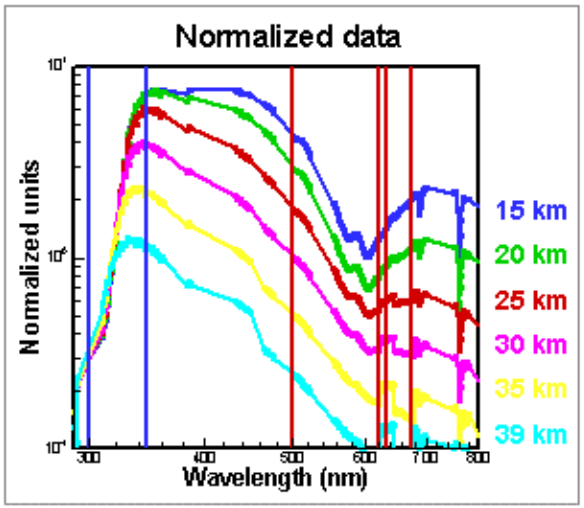
.Forward model: U of Arizona code, modified to perform fast high spectral resolution simulations (no look up tables)

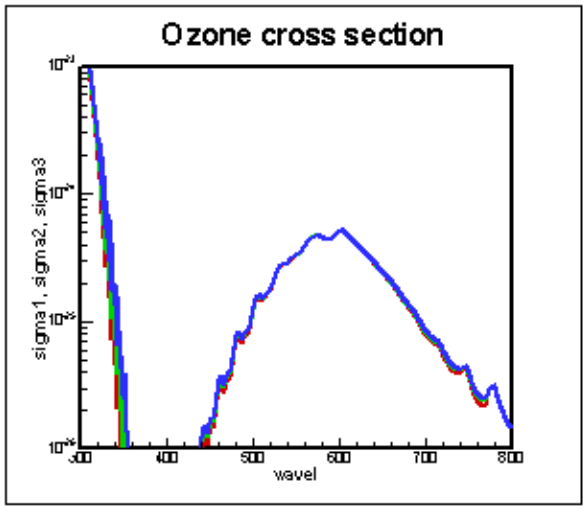
.coupled with SAGE III instrument model



- **MLR method**

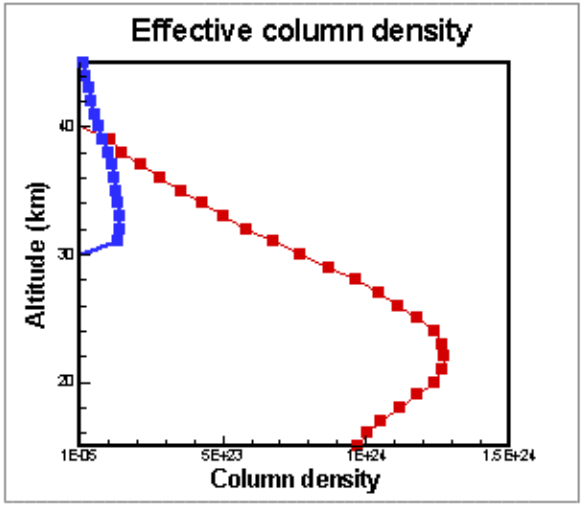
MLR Analysis (1)



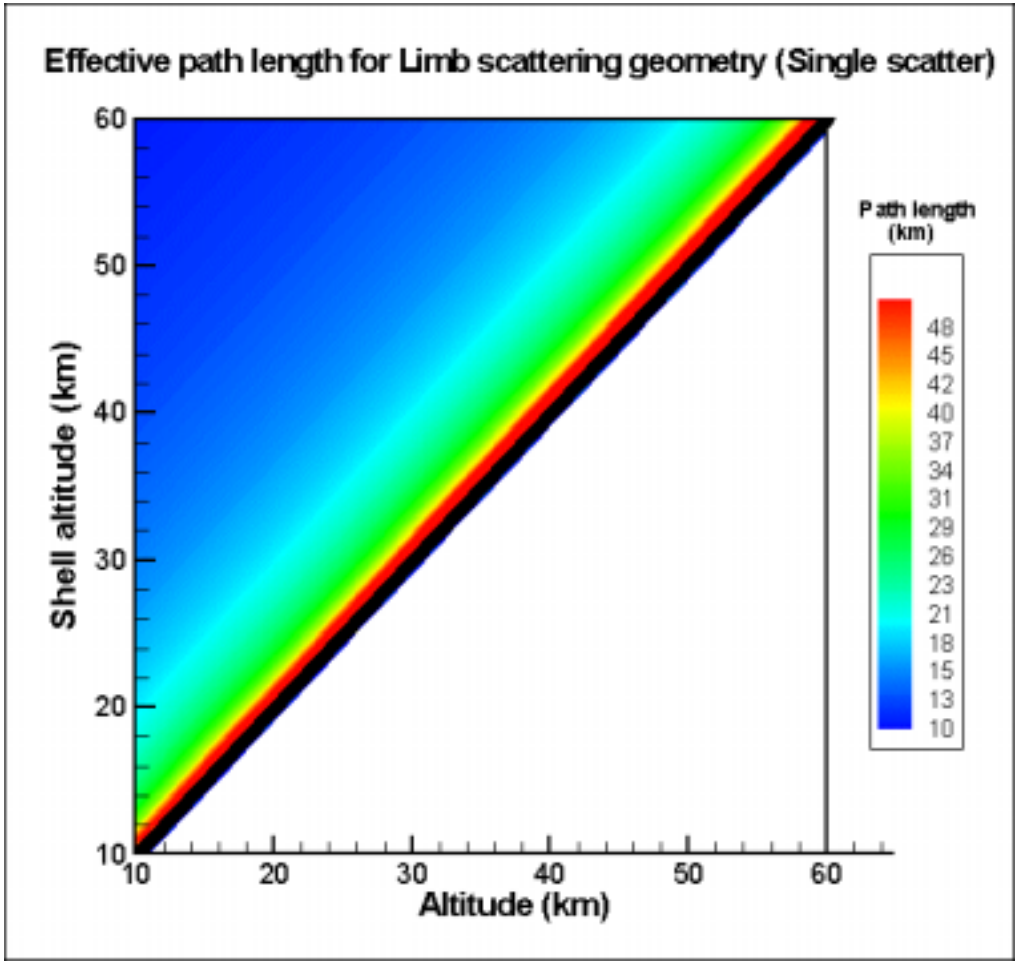


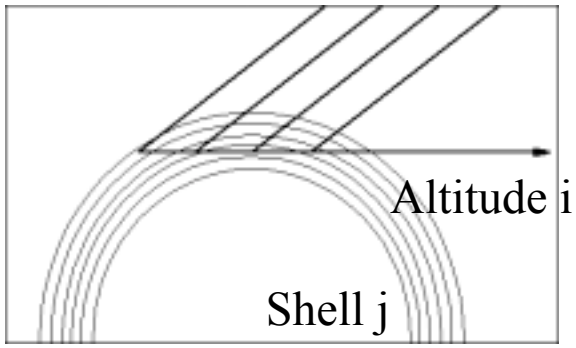
$$\text{Log (radiance / solar)} = -\text{CD} \cdot \sigma(\lambda) + \text{A} + \text{B} \cdot \lambda + \text{C} \cdot \lambda^2$$

aerosol



MLR method (2)





For each tangent altitude i

$$CD_{effective}(i) = \sum_{\text{All shells } j} PL(i,j) \cdot n(j)$$

For Single Scattering,

$$R(i,\lambda) = R_0(i,\lambda) \cdot e^{-\sum_{\text{shells } j} PL(i,j) \cdot n(j) \cdot \sigma(j)}$$

So,

$$PL(i,j) = \partial \ln(R(i)/R_0(i)) / \partial n(j) / \sigma(j)$$

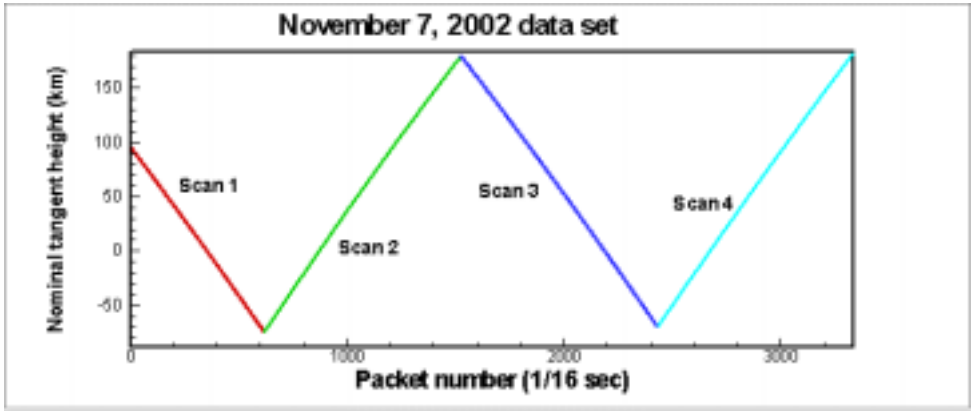
And the density profile is:

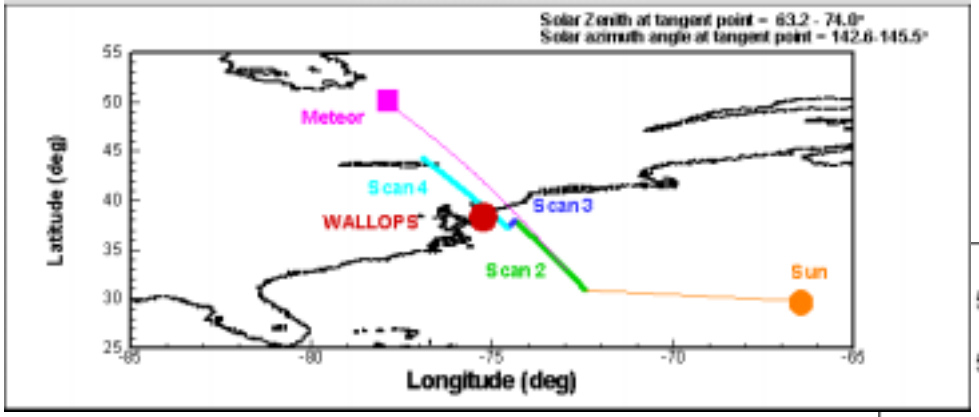
$$[n] = [PL]^{-1} \cdot [CD]_j$$

Tangent Height Registration

- Three methods are being considered to perform height registration of each data point
  - **Dead reckoning**, using the spacecraft state vector and altitude parameters (pitch, roll). This method depends on high accuracy, since an error of one arc minute in angle translates into a mis-registration of 1.0 km
  - **"Knee method"** (Sioris), which considers the shape of the vertical radiance profile around 305 nm, which appears to be invariant wrt ozone density. SAGE III, however, cannot make measurements between 299 and 309 nm, and the method is applied for wavelengths of 309 to 315 nm. Future=295-299nm.
  - **"RSAS"** method(GSFC) which considers the shape of the UV radiance vertical profiles (350 nm)
  - Will investigate **O_2 band** technique (O_2 A, O_2 **B**, O_2 γ bands)

November 7, 2002 Data



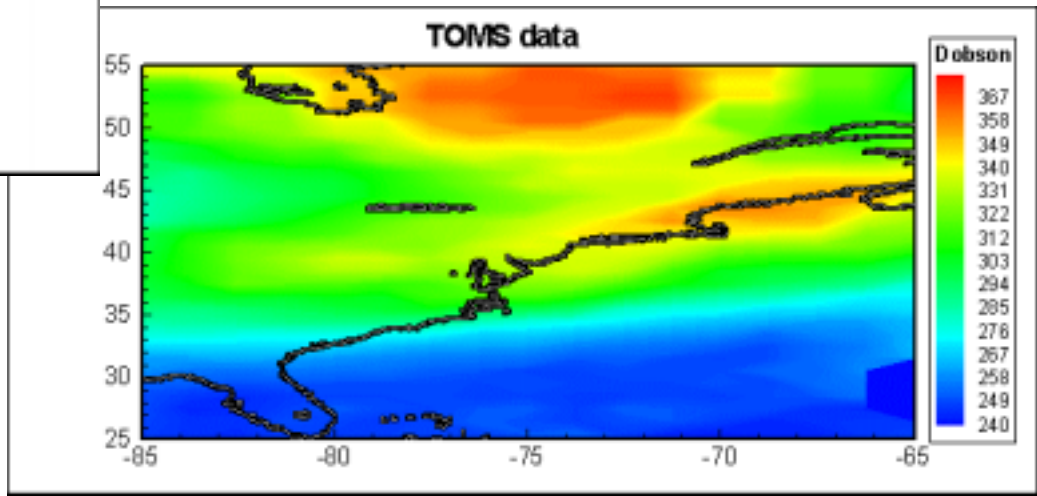


November 7, 2002 data

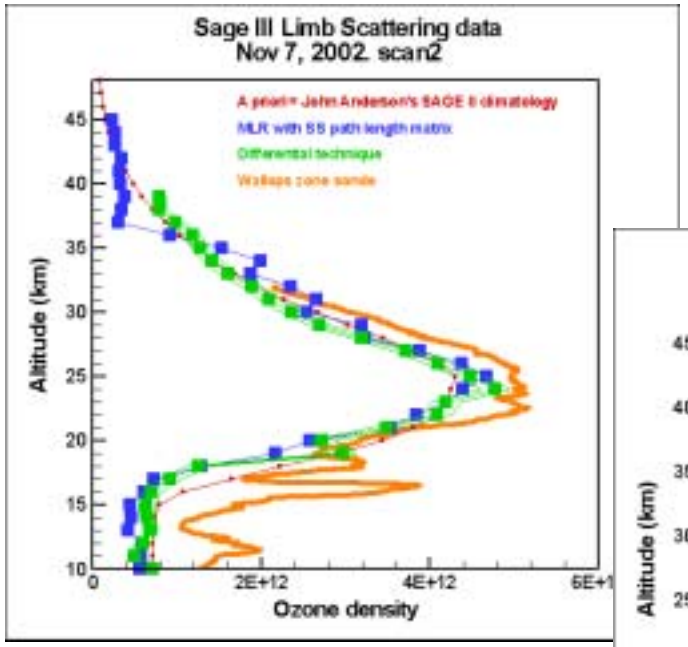
Overpass over Wallops,Va

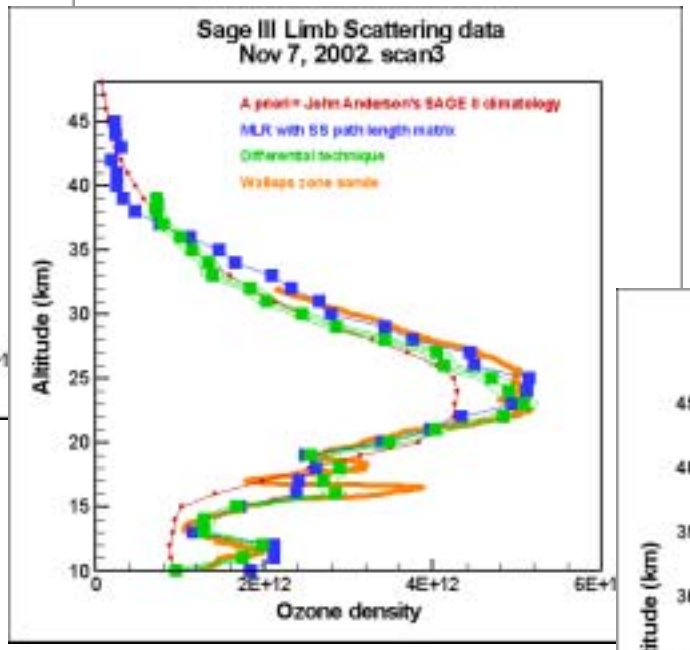
Duration = 5 minutes

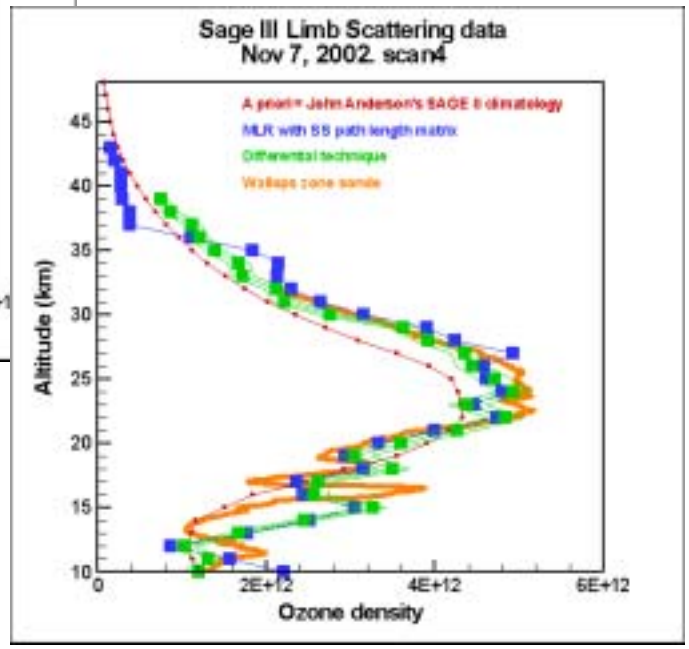
Local Zenith = 63.2 to 74.0



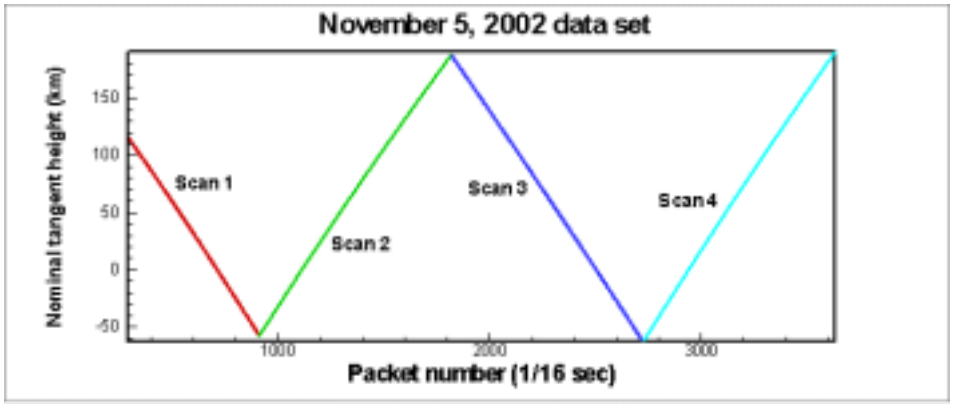
November 7, 2002 Ozone vertical profiles for Scans 2, 3, 4

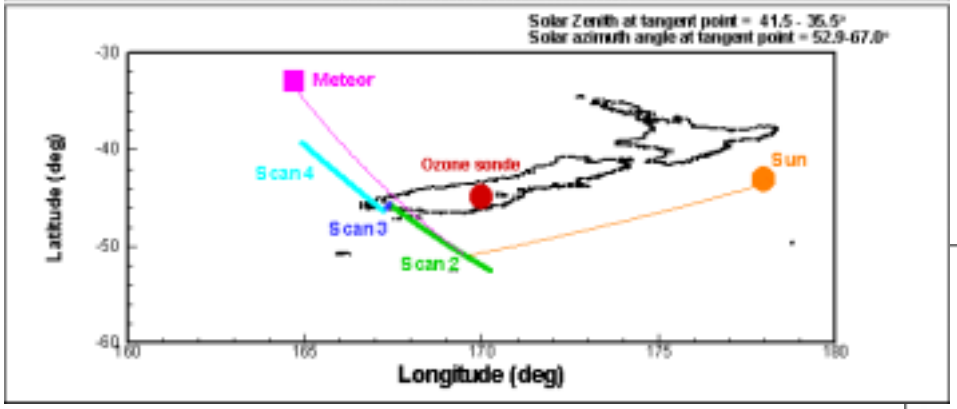






November 5, 2002 Data



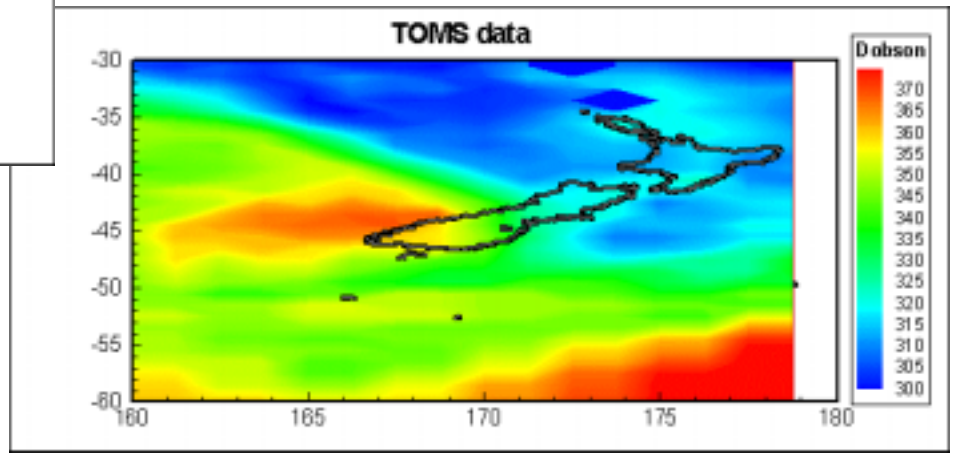


November 5, 2002 data

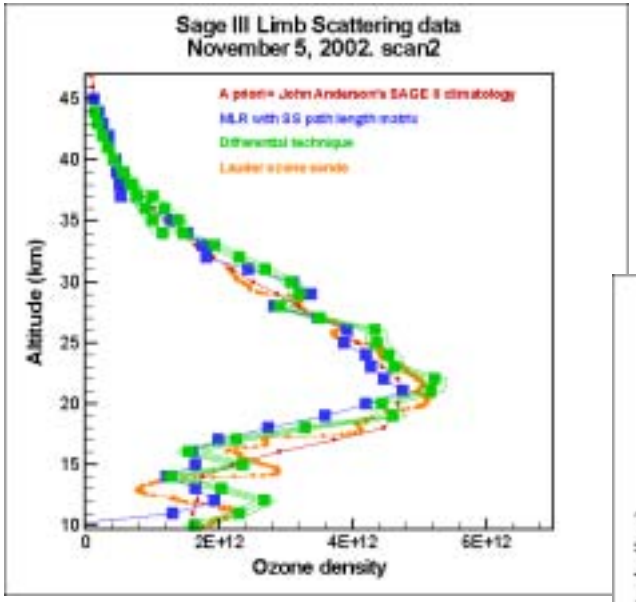
Overpass over Lauder, NZ

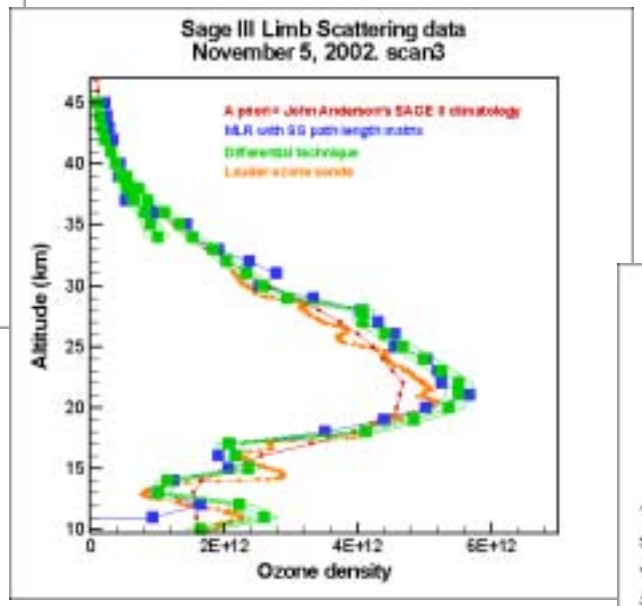
Duration = 5 minutes

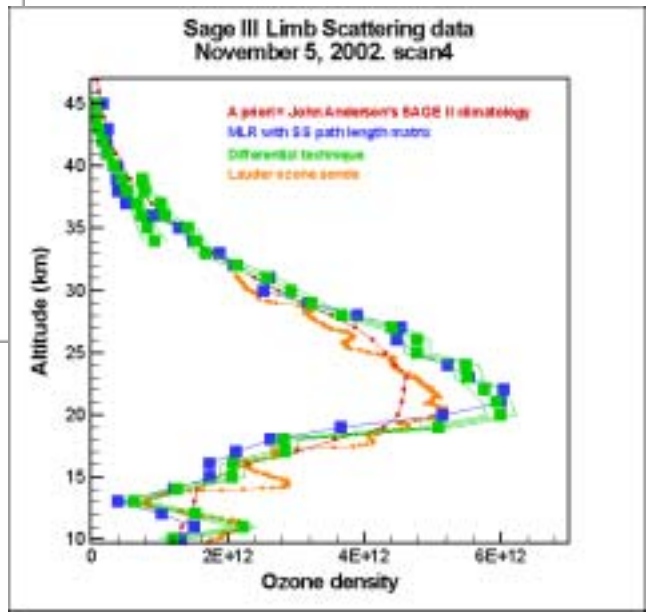
Local Zenith = 41.5 – 35.5



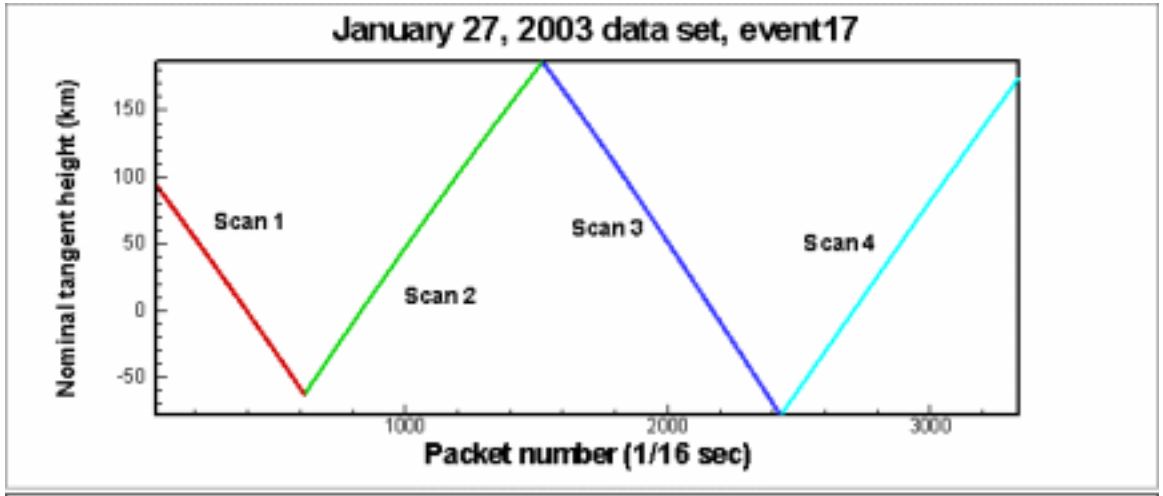
November 5, 2002 Ozone vertical profiles for Scans 2, 3, 4

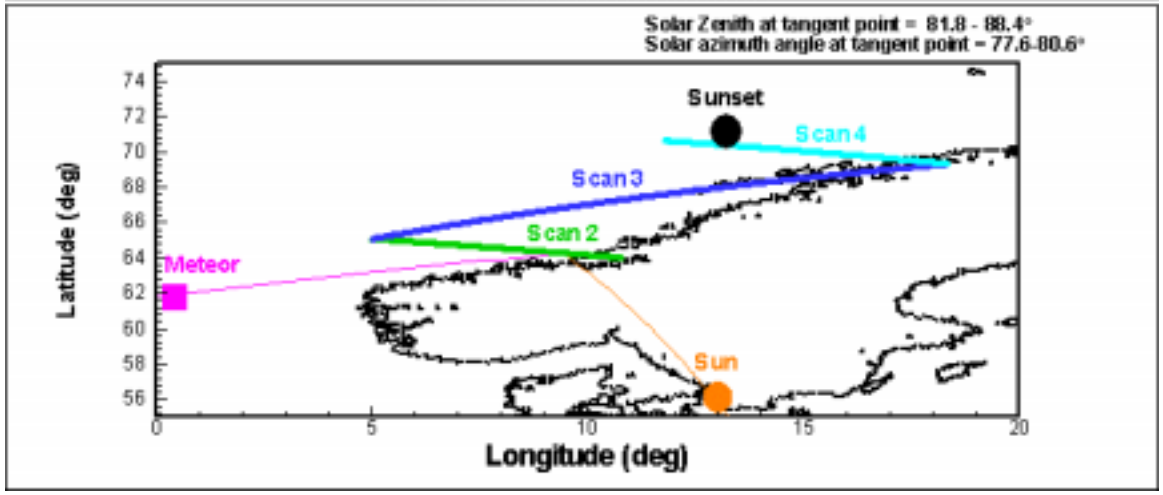






January 27, 2003 Data





January 27, 2003 data

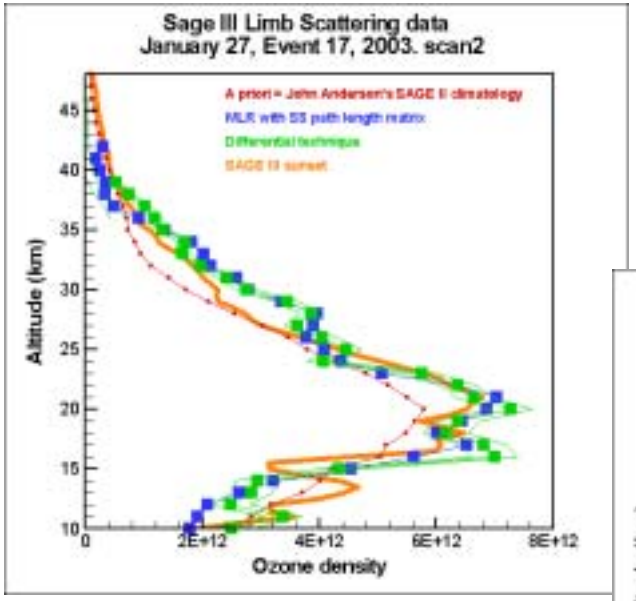
SOLVE, SOLSE/LORE,

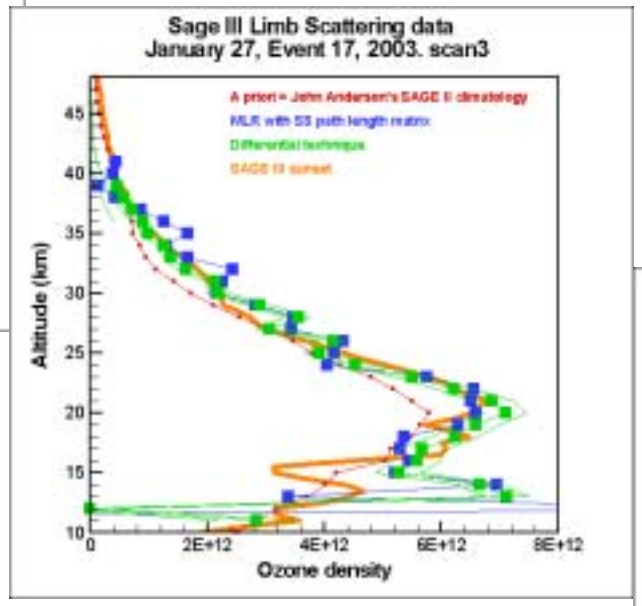
SAGE III Sunset

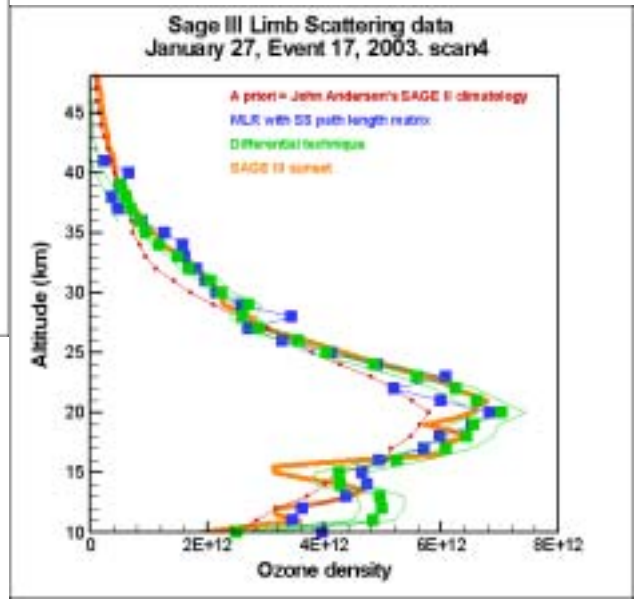
Duration = 5 minutes

Local Zenith = 81.8 – 88.4

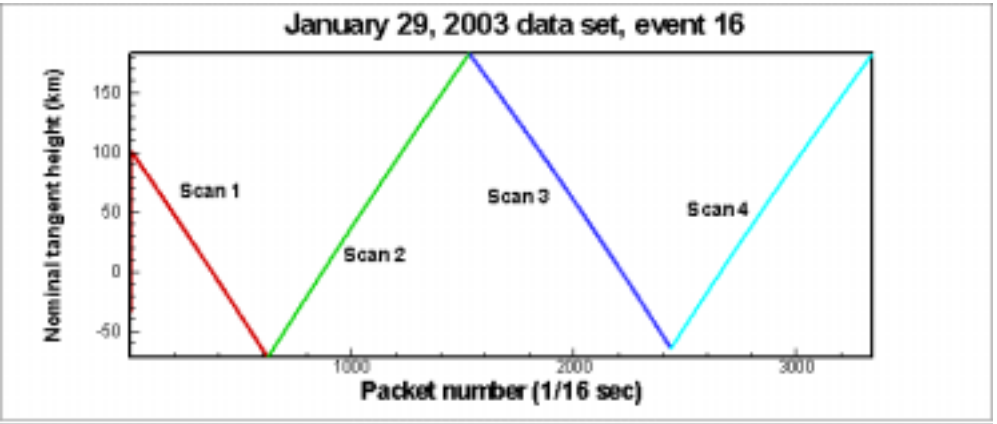
January 27, 2003 Ozone vertical profiles for Scans 2, 3, 4

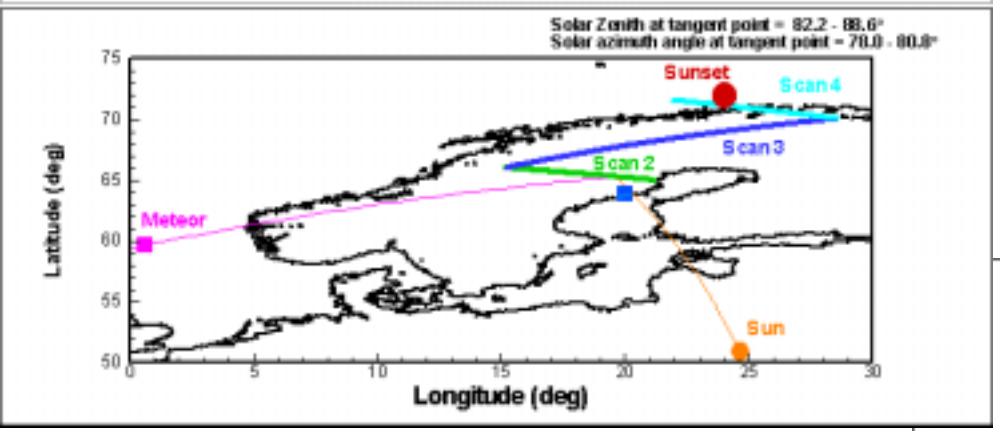






January 29, 2003 Data



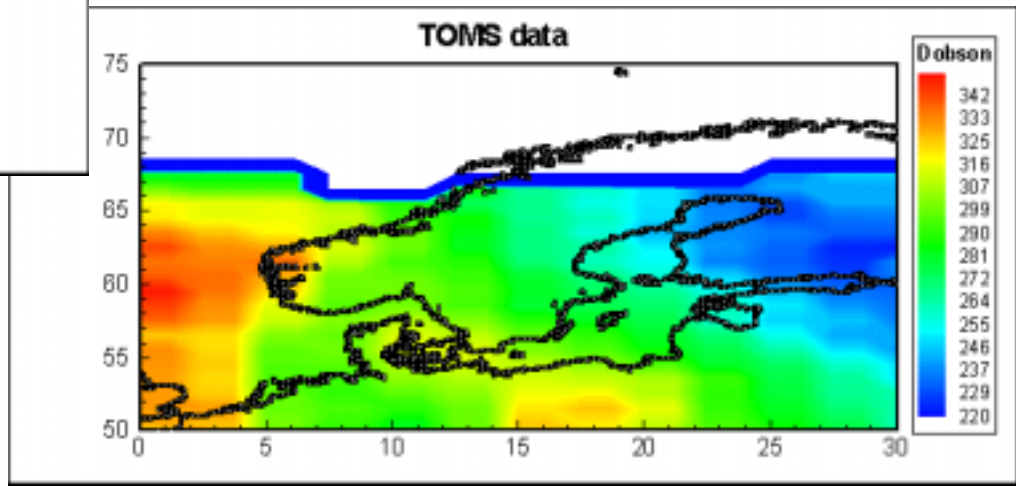


January 29, 2003 data

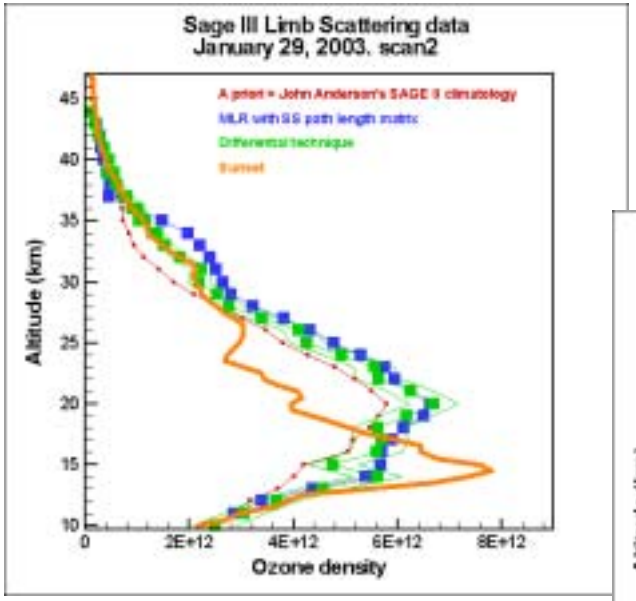
SAGE III Sunset

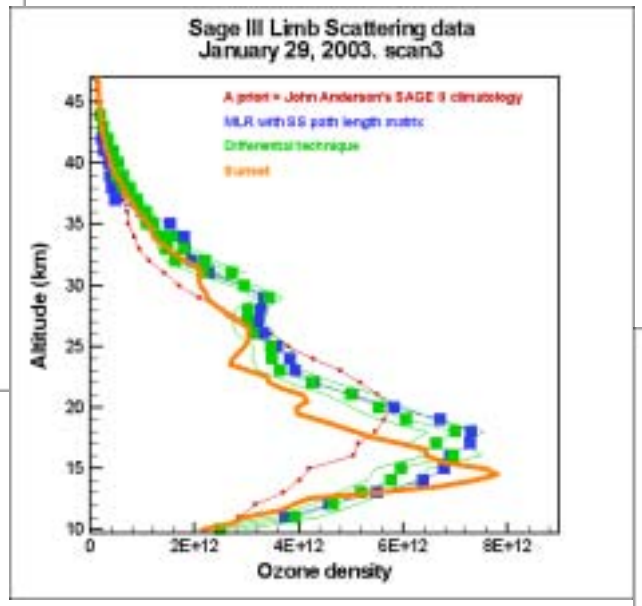
Duration = 5 minutes

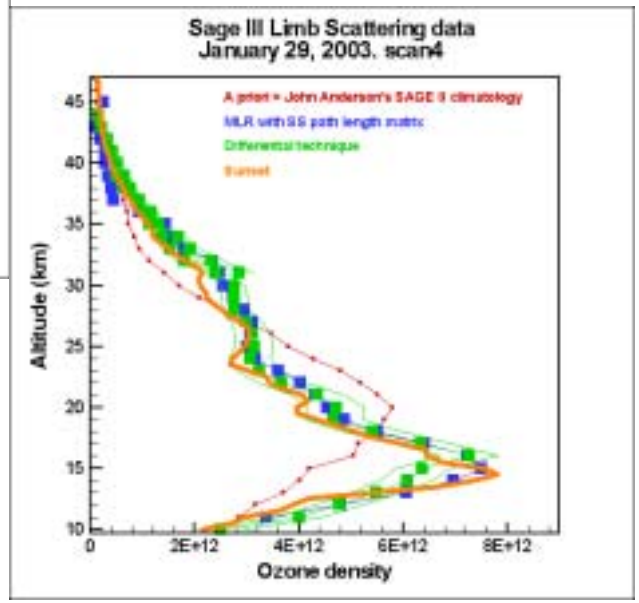
Local Zenith = 81.8 – 88.4



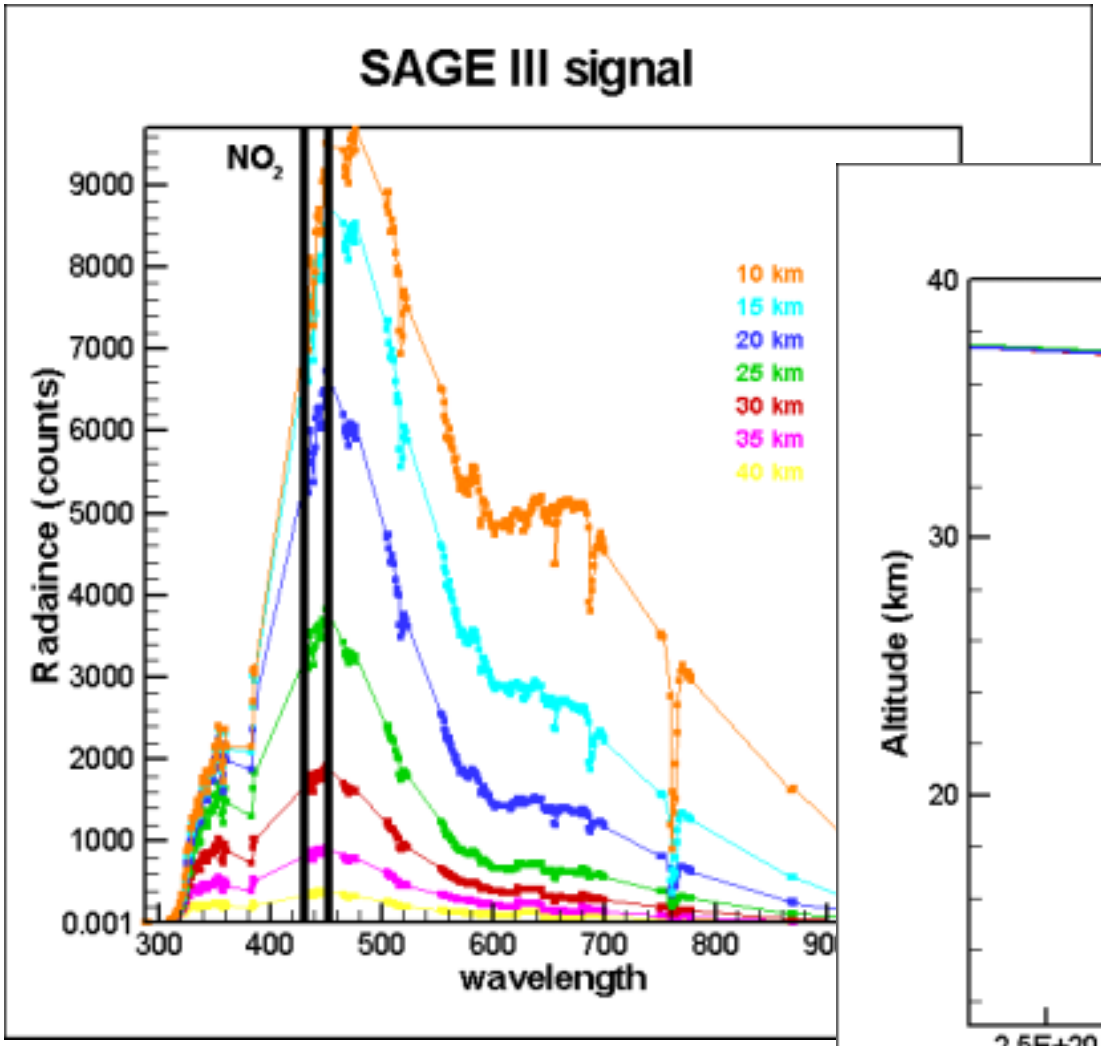
January 29, 2003 Ozone vertical profiles for Scans 2, 3, 4

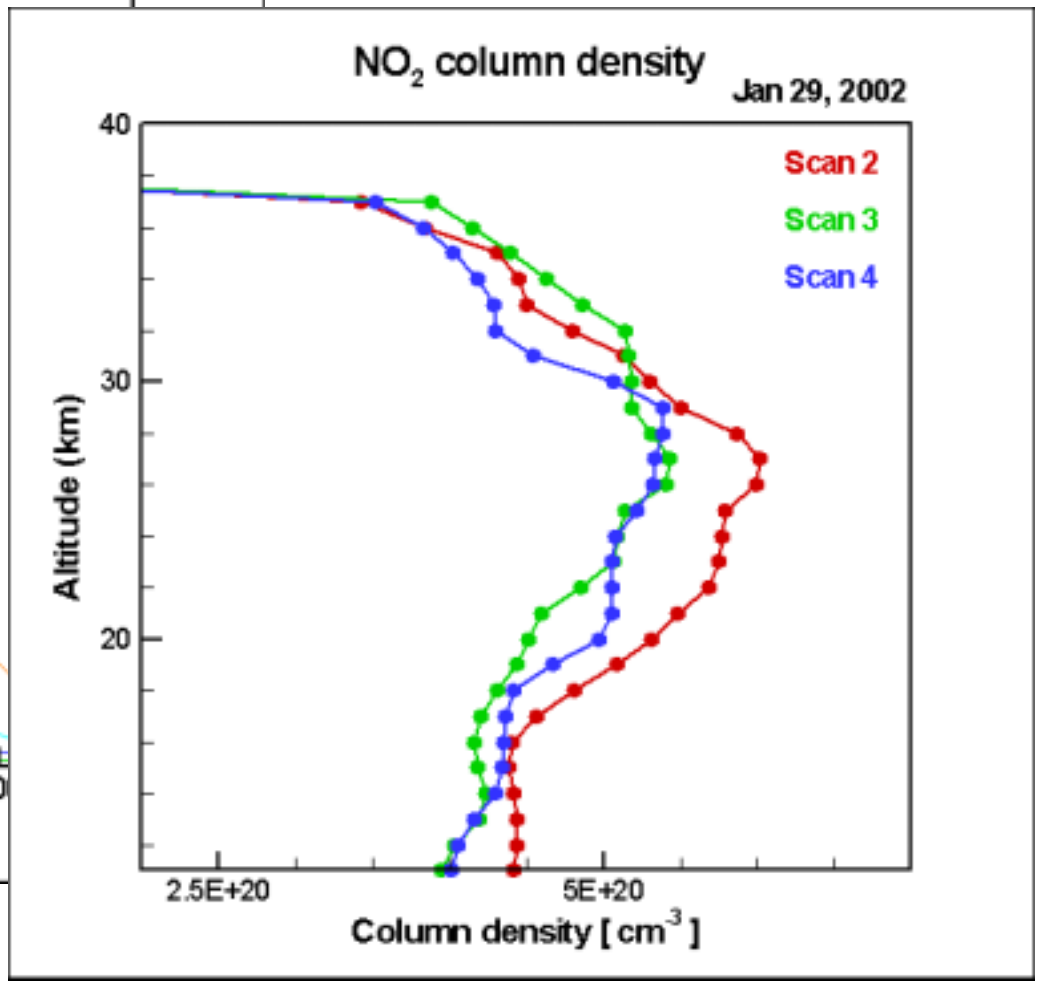






NO2 Retrieval





Conclusion

The initial results show the potentials of SAGE III in limb scattering mode. Ozone profiles have been retrieved from limb radiance measurements, and compared with Ozone sonde measurements and occultation retrievals. Further comparisons will be made with other instruments such Lidars (SOLVE mission), SOLSE/LORE, SCIAMACHY, OSIRIS.

Stray light is a major issue with SAGE III in limb scattering mode and needs to be further characterized. (Lab and Space)

Pointing / Altitude registration is another major issue (all limb instruments)

Other species will be investigated (NO_2, Aerosol)

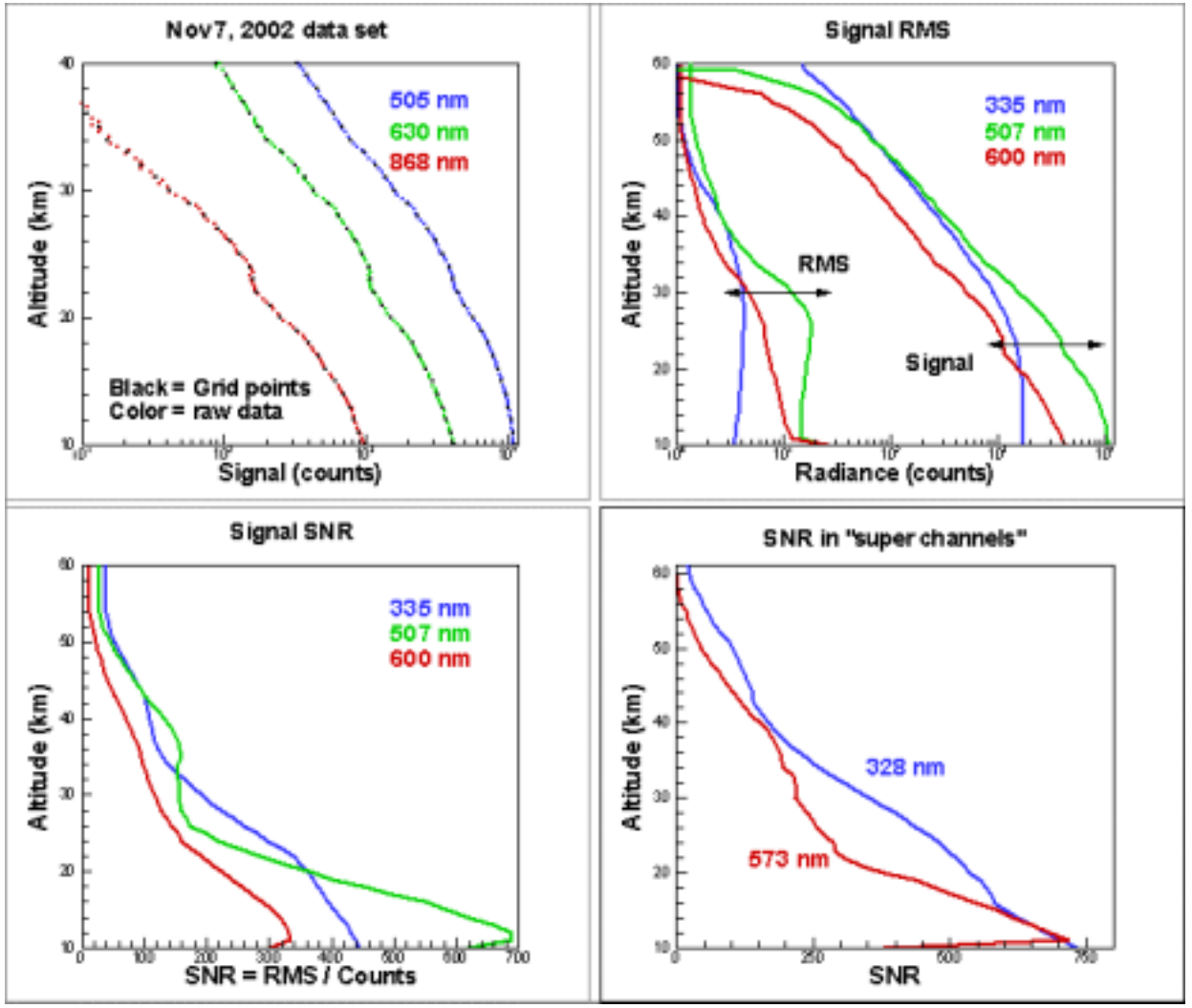
SAGE III Limb scattering available data (1)

Date	Time (UTC)	Duration	Latitude	Longitude	Coincidence
September 6, 2002	09:30	5 minutes	-41 to -29	5 to 0	
November 2, 2002	11:52	5 minutes	-63 to -79	123 to 65	
November 2, 2002	13:38	5 minutes	-63 to -78	92 to 50	
November 2, 2002	15:22	5 minutes	-63 to -77	68 to 20	
November 2, 2002	17:08	5 minutes	-63 to -78	41 to 0	
November 2, 2002	22:40	5 minutes	-56 to –34	176 to 166	
November 3, 2002	16:37	5 minutes	27 to 42	-113 to -118	
November 4, 2002	13:42	5 minutes	28 to 44	-72 to -75	
November 5, 2002	22:39	5 minutes	-54 to –34	75 to 168	Ozone sonde
November 6, 2002	16:35	5 minutes	28 to 42	113 to 118	
November 7, 2002	13:40	5 minutes	32 to 47	-70 to -75	Ozone sonde
November 8, 2002	22:36	5 minutes	-53 to –36	75 to 168	
November 9, 2002	16:34	5 minutes	28 to 44	112 to 118	
November 10, 2002	13:40	5 minutes	32 to 46	-69 to -75	
January 27, 2003	1:46	5 minutes	-10 to 4	111 to 115	SOLSE/LORE/SOLVE
January 27, 2003	3:37	5 minutes	10 to 23	80 to 92	SOLSE/LORE/SOLVE
January 27, 2003	5:25	5 minutes	18 to 31	55 to 51	SOLSE/LORE/SOLVE
January 27, 2003	7:10	5 minutes	16 to 29	29 to 25	SOLSE/LORE/SOLVE
January 27, 2003	10:39	5 minutes	4 to 15	61 to 70	Sunset/SOLVE

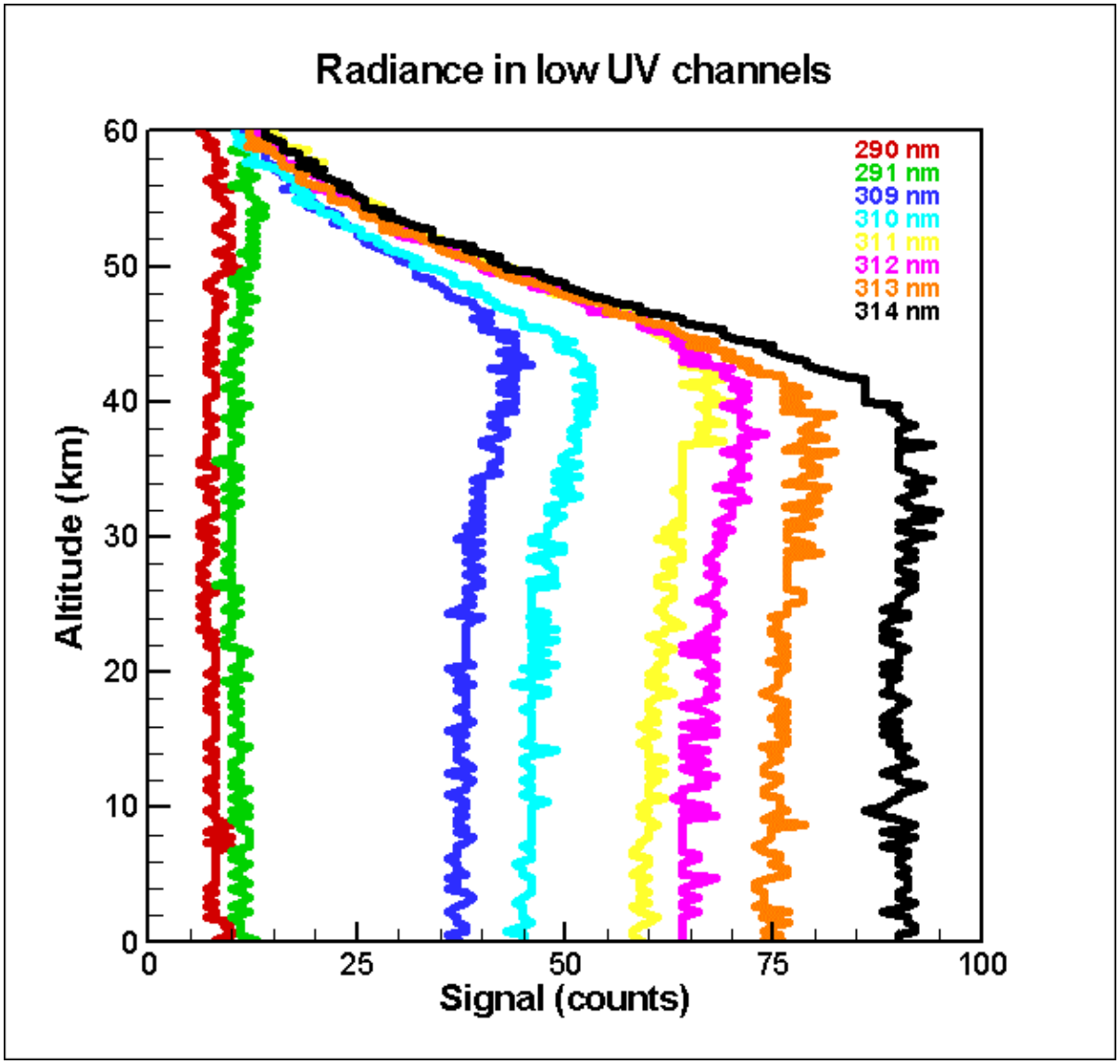
SAGE III Limb scattering available data (2)

Date	Time (UTC)	Duration	Latitude	Longitude	Coincidence
January 28, 2003	0:30	5 minutes	-30 to -17	138 to 134	
January 28, 2003	2:23	5 minutes	-1 to 12	103 to 100	
January 28, 2003	4:14	5 minutes	15 to 28	73 to 70	
January 28, 2003	6:00	5 minutes	18 to 32	46 to 42	
January 28, 2003	10:20	5 minutes	10 to 25	61 to 70	Sunset
January 29, 2003	1:06	5 minutes	-20 to -6	126 to 123	
January 29, 2003	2:59	5 minutes	6 to 19	93 to 90	
January 29, 2003	4:48	5 minutes	17 to 30	64 to 67	
January 29, 2003	6:33	5 minutes	17 to 31	38 to 34	
January 29, 2003	10:02	5 minutes	14 to 25	62 to 70	Sunset
January 30, 2003	1:44	5 minutes	-11 to 2	115 to 112	
January 30, 2003	3:36	5 minutes	11 to 24	84 to 80	
January 30, 2003	5:23	5 minutes	18 to 31	55 to 52	
January 30, 2003	7:08	5 minutes	17 to 30	29 to 26	
January 30, 2003	9:40	5 minutes	10 to 25	61 to 70	Sunset

Signal SNR


Nov7, 2002 data set
505 nm
630 nm
868 nm
Black = Grid points
Color = raw data
Altitude (km)
Signal (counts)
Signal RMS
335 nm
507 nm
600 nm
RMS
Signal
Altitude (km)
Radiance (counts)
Signal SNR
335 nm
507 nm
600 nm
Altitude (km)
SNR = RMS / Counts
SNR in "super channels"
328 nm
573 nm
Altitude (km)
SNR

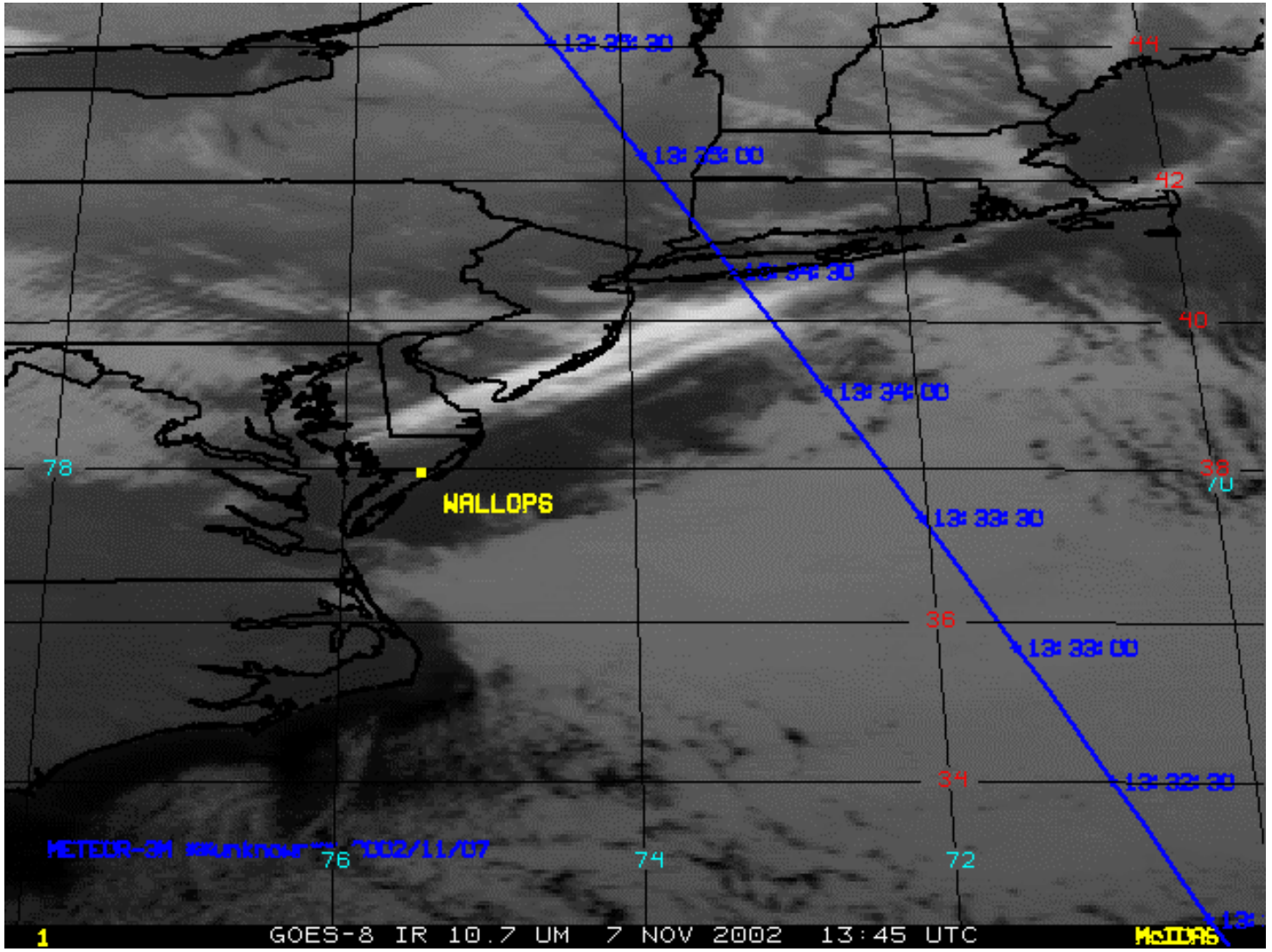
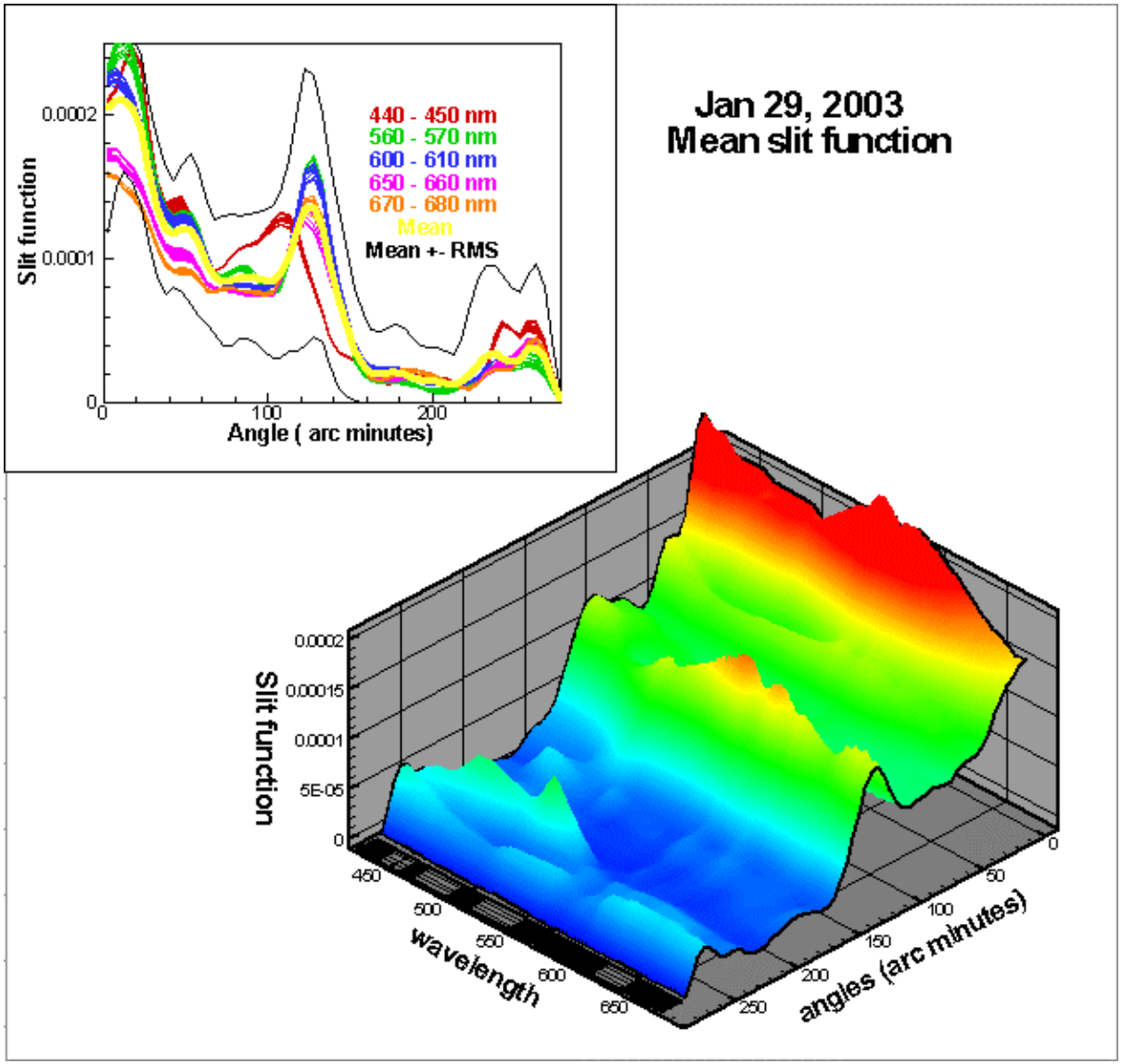
Radiance in Low UV Channels



Data Analysis Procedure

- Read Level 0 data
- Read orbit and spacecraft attitude data
- Wavelength registration
- Correct for bias, mirror reflectivity (λ,a)
- Ephemeris → sun position, 0^{th} order altitude registration
- Stray light removal
- Define atmosphere T, P
- Refraction height correction
- Altitude registration (RSAS)
- Grid Data (1km)
- Read climatology
- Prepare data (height normalization, wavelength grouping, triplets,…)
- Retrieve effective surface reflectivity
- Retrieve Ozone

November 7, 2002 SAGE III limb measurement



Mean Slit Function
January 29, 2003